BIOE 414 **Biomedical Instrumentation** Spring 2025

Course Information

Meeting Time	MWF 11:00 – 11:50 am
Location	CIF 4025
Credits	3 Undergraduate

Meeting links and login information will be provided in Canvas

Course Contact Information

Instructor:	Professor Joseph Irudayaraj
Phone:	217-300-0525 (??)
Email:	jirudaya@illinois.edu
Office	Everitt 3106 or Biomedical Research Facility, 3rd Floor Mills BCI, Carle Hospital S.
Office hours	MW 11:50am -12:30 pm in class and office. Extra hours can be scheduled for in person or Zoom meeting (if zoom, use that weeks' Monday zoom link];

Recommended Textbook: Fundamentals of Electrical Circuits, 7th Edition, Charles Alexander and Matthew Sadiku McGraw Hill. ISBN 978-1-260-22640-9 (bound edition) or ISBN 978-1-260-47767-2 (loose leaf edition)
Textbook and Homework bundle is available online from McGraw HillConnect

Other Reference Text: *Medical Instrumentation: Application and Design*, 4th ed. John Webster (editor). (ISBN: 978-0-471-67600-3). Available in print, e-text, and on reserve in Grainger Engineering Library [Selected sections in Chap 1, 4, 5, 6]

Software: Any circuit simulation package can be used to analyze/test circuits for you Final Project. Examples are LTSPICE (available from National Instruments). Other packages such as Multisim (a more user-friendly Circuit analysis software with National Instruments, I have requested Engineering IT to obtain a campus license), Simulink, etc can be used as well. Multisim is easier to use and there might be a free online option for up to a month.

Assignment Submission: Canvas

Additional online resources are linked in on the course website and in Canvas.

Teaching Assistant

TA	Daniel Um, PhD student in Bioengineering
Email	um5@illinois.edu
Office Hours	Time and Meeting place TBD Zoom by appointment

Course Grader/Assistant

CA-1	Justin Chen [A highly resourceful course assistant!]
Email	justin29@illinois.edu

Website: https://canvas.illinois.edu/courses/56432

Course Format
In person. Lectures will be available via icloud

Course Description

BIOE 414 is a 3rd year course taken by all Bioengineering students and some ECE students.

Catalog Definition: Engineering aspects of the detection, acquisition, processing, and display of signals from living systems; biomedical sensors for measurements of biopotentials, ions in aqueous solution, force, displacement, blood pressure, blood flow, heart sounds, respiration, and temperature; therapeutic and prosthetic devices; medical imaging instrumentation.

Instructors Definition: Introduce students to the working principles of electronic circuits, biopotentials and circuit representation, biomedical transducers, and their applications in biomedical engineering. A key goal is to teach students basic electronic circuit design skills in the context of biomedical applications through problem solving and projects which involves biomedical/biopotential circuit analysis, signal measurement and processing.

Course Outcomes

1. Reinforce the fundamentals of electronic circuits
2. Analyze and design operational amplifier and instrumentation amplifier circuits to amplify biosignals
3. Analyze and design filter circuits to filter unwanted signals from biosignals
4. Understand action potential, origin of cardiac and muscle biosignals and how they are acquired using ECG circuits
5. Understand electrode circuit models and how they affect signal acquisition.
6. Describe and compare methods and instrumentation needed to measure physiological signals in the body.
7. Understand the limitations of instrumentation in terms of accuracy, resolution, precision, and reliability.
8. Function and interact cooperatively and efficiently as a team member in timely completion of a project.
9. Ability to utilize external resources (software) to evaluate and test biomedical circuits
10. Presentation of work in both written and oral reports.
11. Participation in class activities

Assignments and Grading

In-class activities & Participation

- Each in class period will focus on learning the concepts and problem solving – As expected, problem solving will be emphasized so the student becomes more conversant with the fundamentals of biomedical Circuits.
- Please make an attempt to review the class slides prior to the class
- Lecture Videos via icloud are expected to be watched if you miss a class
- Participation of in-class activities

Homework

Homeworks will be assigned approximately once per 1-1.5 weeks and posted in Canvas. These are due by the indicated due dates. Late HWs will be assessed a 10% penalty per day. Overall, you can expect 8 HW's emphasizing problem solving in circuit and instrumentation design and reporting analysis.

Quizzes

There will be a total of 7 quizzes distributed throughout the semester – You can miss 2 Quizzes (please apply this for medical/family emergencies) the best of 5 will be taken. Each quiz will be worth 10 points (lasts ~15 minutes). Quizzes are meant to provide an opportunity to reinforce the basic concepts learnt in the course and will most likely be conceptual in nature or include a basic problem solving to reinforce the application of the concepts discussed in class. Only those on university business will be offered a retake (representing UIUC/GCOE in profession/athletics, with official documentation). For reasons other than this (eg. medical - sickness, personal etc) please use the option to miss. I will take the best of (n-2) quizzes. All quizzes will be announced atleast one class prior – I will make every effort to give one week notice.

Exams

There will be two midterm exams and a final exam. Tentatively, **Exam 1 is scheduled for Feb 24th** and **Exam 2 is scheduled for April 2nd** (in class). Usually 5-6 problems – further details will be provided in class and reinforced in several previous classes. Exams will be closed book and closed notes – a formula sheet will be provided (and posted in Canvas 1-2 classes prior to the Exam). The final exam (**Exam 3**) will be as scheduled by the Registrar's Office - check for the date, time, and location of the exam (will be announced).

Guidelines for Homework/In-class work/Quizzes:

- Homework, in-class work, or quizzes may be used throughout the semester to evaluate student's understanding of topics.
- Expect two of the homework to be team-based and will focus on testing/analyzing instrumentation circuits related to bioinstrumentation or discussion on biomedical sensors
- We will use **Canvas** (https://www.canvas.illinois.edu/) for submitting and grading homework. Instructions on how to submit assignments on Canvas is posted on the course website.
- Please write legibly. Only what is legible will be graded; all else will be marked as no credit. Use adequate line spacing to improve clarity and legibility.
- Deadlines will be set for each assignment on the assignment sheet and posted in Canvas. Late submission will be accepted with penalty up to a certain time limit.
- Other Submission etiquette.
    - Box your answer.
    - Include units where appropriate.
    - Please use a pen because work done in pencil may not be very visible when you pdf your work for submission
    - When plotting functions, use a computer program like MATLAB or a ruler and graph paper. Include a title and axes labels on all plots.
- **Participation:** Participation will be based on student's attendance (sign-up sheet will be passed around on an average 1-2 times/week), interaction during class (Q&A, group discussions, and participation), project presentation, and discussion (in class sessions). If a class is missed due to a university approved absence, please alert the course instructor. Make-up assignments will be considered and assigned on a case-by-case basis and will only be an option for documented, University approved absence.
- **Accommodations related to health will be made consistent with the Grainger College of Engineering and UIUC guidelines**
- **Please follow all safety and precautionary measures as required by UIUC guidelines**
- **If you have any other considerations, please discuss with the instructor**

Quick Checklists

To encourage you to stay on track with the course, quizzes will emphasize concepts you should have mastered – Materials for each module will be posted in Canvas. Stay current with assignments. If you miss a class, it is your responsibility to obtain/access materials missed due to absence. Check Canvas for schematic of circuit diagrams or problems prior to class.

Conflict

A conflict exam will only be offered if 1) another exam or course in which the student is enrolled occurs at the same time as the BIOE 414 exam and that exam was scheduled prior to BIOE 414; 2) health/medical emergency with a signed note from a certified physician/healthcare provider. Appointments with physicians for medical/physical checkup etc are not emergency and will not be considered as conflict. For conflict exams due to other courses, documentation on the conflict from the other course's instructor will be required; in addition, documentation for not being able to take the other course's conflict exam will be required.

Project Work & Team Assignments

There will be a group project worth 10% of your final grade. It should involve topics in biomedical circuits and/or signal conditioning, and/or instrumentation related to the course. The teams (3-4) are expected to create a presentation on the topic and submit a report. All group members will be given the same score unless special issues are raised by group member(s). Emphasis will be on Bioinstrumentation Circuit Design, Circuit analysis (use LTSpice) in the context of application. More information will be provided in class and in project outline handout in Canvas. For project work and team assignments, **one team submission** should suffice.

Email Policy: Most course correspondence will occur through the Canvas.Illinois.edu site OR direct email to the TA or Instructor or grader. When you email regarding the course, please include "BIOE 414: Topic of discussion" in the subject line. Emails will be answered within 24 hours M-F. Prof. Irudayaraj usually answers the questions almost instantaneously. Do email the TA and/or Grader for questions related to grading of Homework and Quizzes.

Grade and Scaling: The following is a summary of points that will be counted towards the grade. Based on student performance, final grades may be curved.

Homework:	15%
Exam 1:	20%
Exam 2:	20%
Exam 3:	20%
Quizzes:	10%
Project:	10%
Class Participation:	5%

Grade	Percent
A+	>=98
A	>=91
A-	>=89
B+	>=87
B	>=81
B-	>=79

Grade	Percent
C+	>=77
C	>=71
C-	>=69
D+	>=67
D	>=61
D-	>=59
F	<59

Expectations

Course Best Practices

Tips to be successful in Biomedical Instrumentation:

- Participate and pay attention in lecture (ask questions, answer questions, take notes, complete activities).
- Review the lecture the same day – **for those with minimum exposure to circuit fundamentals, it is all the more important to spend atleast 30 min (perhaps more if time allows) after class to review the material discussed**
- Participate in the Canvas discussion board and chatrooms (respond to instructor prompts, ask questions, and be a team player), as needed (**may not apply if In Person instruction**)
- Complete the quizzes and quick review assignments on time.
- Do the practice problems outside of class and make sure you can complete problems on your own.
- Promptly review feedback and solutions provided. Ask questions if you do not understand the feedback or need additional details.

- Utilize the TA hours
- Discuss in groups – but solve the problems on your own
- **Reach out early so we can help you and do not wait till the last minute or after your Exam 2 – We are here to help**

Attendance

Course attendance is expected and is part of Class participation grade. Signup sheets will be used for this purpose (approx. 1-2 per week on an average). In case class is missed due to a university approved absence, please notify the course instructor. Written documentation will be required. Make-up work will be considered and assigned on a case-by- case basis and will only be an option for documented, University approved absences. Additionally, any make up assignments must be completed by the next class to receive any credit (unless pre-approved delay beyond the one class has been approved).

Netiquette

In any social interaction, certain rules of etiquette are expected and contribute to more enjoyable and productive communication. The following are tips for interacting online via e-mail or discussion board messages, adapted from guidelines originally compiled by Chuq Von Rospach and Gene Spafford (1995):

- Remember that the person receiving your message is someone like you, deserving and appreciating courtesy and respect
- Avoid typing whole sentences or phrases in Caps Lock
- Be brief; succinct, thoughtful messages have the greatest effect
- Your messages reflect on you personally; take time to make sure that you are proud of their form and content
- Use descriptive subject headings in your e-mails
- Think about your audience and the relevance of your messages – please avoid using a blanket "Hi" followed by your message, in all official correspondence.
- How to address the Instructor: "Dear Professor Irudayaraj"
- How to address the Teaching Assistant/Grader: "Dear/Hi/Hello Daniel/Daniella"
- How to conclude the email – Please end with a "Thank you" or "Regards" or "Best".
- Be careful when you use humor and sarcasm; voice inflections and body language that aid face-to-face communication is absent in emails so interpretation of your email may be different from what you might think/mean – choose words carefully, Internet messages are easy to misinterpret.
- Keep in mind, sometimes a 1-2 min in person discussion is more effective
- Keep your email short, unless something needs to be explained and described
- Avoid needless repetition
- Cite appropriate references whenever using someone else's ideas, thoughts, or words
- Finally, we all make mistakes – just be cautious and send a followup message

Other tips for being an online student (when applicable): **Illinois Online:** https://online.illinois.edu/articles/online- learning/item/2020/03/12/adapting-to-online-learning

Unforeseen Circumstances

As many aspects of this semester are unprecedented due to the public health emergency, schedules and expectations may need to adapt to unforeseen circumstances. The instructor, the teaching assistant, and the grader will be working to provide resources for you to be able to learn the material and achieve the

BIOE414 objectives and most of all to keep you updated. However, as the situation changes the course and expectations of the course may need to be adapted as well. If changes occur, we will communicate them promptly.

Policies

Academic Integrity

The University of Illinois at Urbana-Champaign Student Code should also be considered as a part of this syllabus. Students should pay particular attention to Article 1, Part 4: Academic Integrity. Read the Code at the following URL: http://studentcode.illinois.edu/.

Academic dishonesty may result in a failing grade. Every student is expected to review and abide by the Academic Integrity Policy: https://studentcode.illinois.edu/article1/part4/1-401/. Ignorance is not an excuse for any academic dishonesty. It is your responsibility to read this policy to avoid any misunderstanding. Do not hesitate to ask the instructor(s) if you are ever in doubt about what constitutes plagiarism, cheating, or any other breach of academic integrity.

Disability-Related Accommodations

To obtain disability-related academic adjustments and/or auxiliary aids, students with disabilities must contact the course instructor prior and the Disability Resources and Educational Services (DRES) as soon as possible. To contact DRES, you may visit 1207 S. Oak St., Champaign, call 333-4603, e-mail disability@illinois.edu or go to https://www.disability.illinois.edu. If you are concerned you have a disability-related condition that is impacting your academic progress, there are academic screening appointments available that can help diagnosis a previously undiagnosed disability. You may access these by visiting the DRES website and selecting “Request an Academic Screening”. Please alert the instructor or have the DRES reach out to the instructor.

Emergency Response Recommendations

Emergency response recommendations can be found at the following website: http://police.illinois.edu/emergency-preparedness/. I encourage you to review this website and the campus building floor plans website within the first 10 days of class. http://police.illinois.edu/emergency-preparedness/building-emergency-action-plans/.

Anti-Racism and Inclusivity

The intent is to increase student and instructor awareness of the ongoing threat of bias and racism and of the need to take personal responsibility in creating an inclusive learning environment.

The Grainger College of Engineering is committed to the creation of an anti-racist, inclusive community that welcomes diversity across dimensions, including, but not limited to, race, ethnicity and national origins, gender and gender identity, sexuality, disability status, class, age, or religious beliefs. The College recognizes that we are learning together amid the Black Lives Matter movement, that Black, Hispanic, Indigenous and several other minority group voices and contributions have largely either been excluded from, or not recognized in, science and engineering, and that both overt racism and micro-aggressions threaten the well-being of our students and our university community.

The effectiveness of instruction is dependent upon each of us to create a safe and encouraging learning environment that allows for the open exchange of ideas while also ensuring equitable opportunities and respect for all of us. Everyone is expected to help establish and maintain an environment where students, staff, and faculty can contribute without fear of personal ridicule, or intolerant or offensive language. If you

witness or experience racism, discrimination, micro-aggressions, or other offensive behavior, you are encouraged to bring this to the attention of the course director if you feel comfortable. You can also report these behaviors to the Bias Assessment and Response Team (BART) (https://bart.illinois.edu/). Based on your report, BART members will follow up and reach out to students to make sure they have the support they need to be healthy and safe. If the reported behavior also violates university policy, staff in the Office for Student Conflict Resolution may respond as well and will take appropriate action.

Religious Observances

Illinois law requires the University to reasonably accommodate its students' religious beliefs, observances, and practices regarding admissions, class attendance, and the scheduling of examinations and work requirements. You should examine this syllabus at the beginning of the semester for potential conflicts between course deadlines and any of your religious observances. If a conflict exists, you should notify your instructor of the conflict and follow the procedure at https://odos.illinois.edu/community-of-care/resources/students/religious-observances/ to request appropriate accommodations. If you have prior knowledge about this observance, alert the instructor within the first two weeks of classes and not the week before the exam. I take pride in my familiarity with most of the major religions (and willing to learn) in the world and will work with you on this accommodation.

Sexual Misconduct Reporting Obligation

The University of Illinois is committed to combating sexual misconduct. Faculty and staff members are required to report any instances of sexual misconduct to the University's Title IX Office. In turn, an individual with the Title IX Office will provide information about rights and options, including accommodations, support services, the campus disciplinary process, and law enforcement options.

A list of the designated University employees who, as counselors, confidential advisors, and medical professionals, have this reporting responsibility and can maintain confidentiality, can be found here: wecare.illinois.edu/resources/students/#confidential.

Other information about resources and reporting is available here: https://wecare.illinois.edu/.

Family Educational Rights and Privacy Act (FERPA)

Any student who has suppressed their directory information pursuant to Family Educational Rights and Privacy Act (FERPA) should self-identify to the instructor to ensure protection of the privacy of their attendance in this course. See https://registrar.illinois.edu/academic-records/ferpa/ for more information on FERPA.

Course Topics and tentative calendar of lectures

Week	Date	Topic	Reading	Comments
1		Introduction, Course Outline, Canvas Introductions, Basic Components and Electric Circuits	Chap 1,2	
2		Nodal and Mesh Analysis, Applications, In Class work	Chap 3	Quiz 1
3		Operational Amplifiers, Applications, In Class Work – Application of Op Amps in Instrumentation	Chap 5	Quiz 2
4		Circuit Theorems, Linearity, Superposition, Source Transformation, Thevenin and Norton Theorem, Applications	Chap 4	Quiz 3
5		Capacitors and Inductors – Fundamentals of RC and RL circuits – Capacitive Sensors for health monitoring	Chap 6	Quiz 4 **Exam 1**
6		Sinusoids and Phasors	Chap 9	
7		Phasor Circuits, Filter circuits – Passive filters, Active filters	Chap 9	

8		Instrumentation Amplifiers, Differential Amplifiers, DAC, Amplifier circuit design for solving differential equations	Chap 6, notes	Quiz 5
9		Frequency Response Filters and Applications; LTSPice Circuit Simulator (National Instruments)	Chap 9,14	Quiz 6 **Exam 2**
10		Action Potential – Electrodes – Circuits (Ref. Webster Chap 5) Discussion of Hodgkin-Huxley model. Representation of action potential by a simple circuit and simulation of Response.	Notes	
11		Action Potential – A Circuit model (Continued)	Notes	
12		Action Potential – Electrodes – Noise removal – Basics of Electrochemical Sensing, A Circuit model for a cell – Simulation of I/O using a circuit simulator	Notes	Quiz 7
13		Instrumentation Amplifiers – Electrocardiogram circuit design – design, Common Mode rejection (Ref. Webster Chap 6)	Notes	
14		Medical Instrumentation – Glucose measurement devices, Blood Pressure Monitors, Heart Rate monitors, SIM Center		
15		Q/A, Review session for **Exam 3**		**Exam 3: as scheduled by Registrar's Office**